The only difficulty I see in this explanation is the difficulty of assigning a reason for the flow of air at 8 to 10 kilometers from the cyclonic to the anticyclonic area. This is the height of the strongest winds, and it is easy to ascribe the flow in general terms to the geostrophic and centrifugal action of the wind, but that does not carry us much farther. If it is correct, it means that cyclones are generated in the upper part of the troposphere by the general circulation of the atmosphere and spread downward. Also that there is a slight outflow of air from the cyclone above; it need only be slight, just as there is a slight inflow below near the ground.

A correct theory of the formation and propagation of cyclones must be able to account for the well-marked distribution of temperature in the upper air that accompanies them and the temperature is almost certainly due to dynamic heating and cooling. The changes of temperature accompany the changes of pressure and are large from day to day, far larger than would be possible if they were due solely or chiefly to radiation. It is natural to look to the direction of the wind to account for changes of temperature, but the statistical evidence is perfectly distinct in showing that the direction of the wind, save quite close to the earth, has only a trifling effect upon the temperature. Above 2 kilometers there is no appreciable correlation between the south to north or west to east components of the wind and the temperature. This is the case if the actual surface wind, the *gradient* wind, or the drift of the balloon which carries the instruments be used. Doubtless, as Capt. C. K. M. Douglass urges (R. Met. S. J., Vol. XLVII, No. 197, p. 23), it is the place of origin of the air, not its temporary direction that matters, but in view of the absence of correlation between wind direction in the upper air and temperature it does not seem possible to me that cyclones should be caused by the action of polar and equatorial currents. On the other hand there can be no doubt that the mild winters of western Europe are due to the prevalent southwest and west winds coming from the warm waters of the north Atlantic.

In the suggested explanation of the correlation between pressure and temperature nothing has been said about the time requisite for the adjustment. If the explanation is to be feasible, the time required must be comparatively short; otherwise radiation would prevent the changes of temperature from being adiabatic. If we neglect frictional resistances, it can be shown by elementary dynamical considerations that equalization of temperature between places 200 kilometers apart would take about an hour. The time required varies as the square root of the distance, so that the equalization between two places on the ordinary weather chart is only a matter of an hour or two, in which time radiation would not have much effect. But the assumption that frictional resistances may be neglected is certainly a large one owing to the eddy viscosity of the atmosphere. However, the gradient wind appears to adjust itself with considerable rapidity to the distribution of pressure notwithstanding the eddy viscosity, so perhaps the time is not greatly increased by the same cause. But the retardation due to eddy viscosity will vary as the distance, so that for large distances it may be very considerable. This may explain why differences of mean temperature exist in winter between, let us say, England and eastern Europe at a few kilometers height, though it may be noted that such differences are far smaller than those found at ground level.

AVERAGE FREE-AIR WINDS AT LANSING, MICHIGAN.

C. L. RAY, Observer.

[Weather Bureau, Lansing, Mich., Oct. 14, 1922.]

The first pilot-balloon ascension at this station was made June 10, 1919, and flights have been made daily since that time, except when impossible through inclemency of the weather. Flights were made at 7 a. m. and 3 p. m. until August, 1921. Beginning with the flight of August 1, the morning ascensions were discontinued, and the single flight daily at 3 p. m. has been made since that time.

The results set forth in this paper have been based on the flights made during the three-year period, June 1919–May 1922, inclusive. The number of flights obtained during that time, and listed by seasons and altitudes, follows:

TABLE 1.—*Number of pilot-balloon ascensions, June 1919, to May, 1922, inclusive.*

Altitude.	Spring.	Summer.	Autumn.	Winter.	Annual.
m.					
Surface	364	420	366	324	1,474
250	364	420	366	324	1,474
500	344	414	353	286	1,397
750	323	401	326	242	1,292
1,000	307	394	290	213	1,204
1,500	264	359	254	170	1,047
2,000	231	313	226	143	913
2,500	194	266	177	127	764
3,000	164	235	148	110	657
3,500	136	190	116	87	529
4,000	117	170	94	76	457
4,500	103	152	66	56	377
5,000	85	136	56	40	277
6,000	52	100	34	27	213

The percentage of winds from various directions over this three-year period is shown in Table 2, and as will be noted shows over 50 per cent of the surface winds with a south component and more than 56 per cent with a west component. At 4,000 and 6,000 meters elevation the preponderant direction lies between west and northwest, and slightly favoring northwest. The detailed percentages are as follows:

TABLE 2.—*Percentage frequency of winds observed from various directions.*

Meters.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.
Surface	6	4	5	3	3	3	5	5	9	10	11	8	10	6	8	4
1,000	5	5	4	2	3	2	2	3	5	6	10	11	16	10	11	5
2,000	6	3	4	2	2	2	2	1	2	4	8	12	18	14	12	8
4,000	4	3	4	2	1	1	1	2	2	4	8	7	17	19	16	9
6,000	6	1	4	1	0	3	1	2	1	4	6	8	15	20	21	7

The information contained in this table has been used in the graphical representation (fig. 1), which shows probably to better advantage the results obtained. Above 2,000 meters west to northwest winds generally prevail.

In Table 3 are given the mean free-air winds for the different seasons and the mean annual directions and velocities. Southwest winds prevail at the surface during the spring, summer, and *autumn months, giving* place to a west direction in the winter season. All surface velocities are close to three meters per second

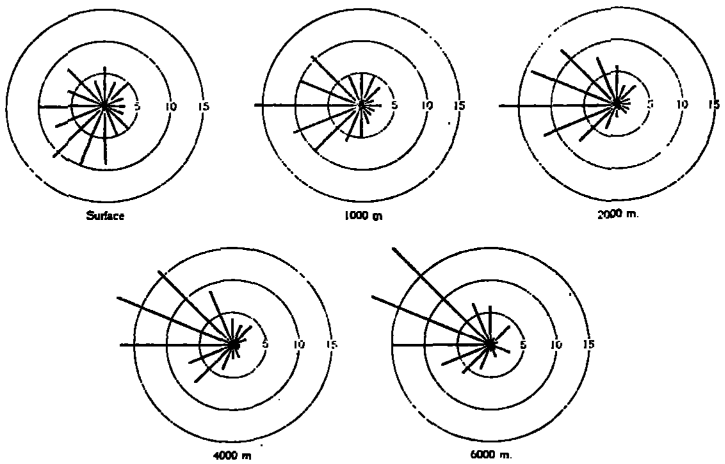

FIGURE 1.—Percentage frequency of winds from various directions at different levels above Lansing, Mich.

with a slightly greater speed during the spring months. At 250 meters, the winds have shifted quite definitely in a clockwise direction and velocities average two and a half times greater than at the surface. Above 1,500 meters a south component is in no instance observable in the means and the winds are consistently west to northwest. Velocities are greatest in the winter months, and at the 6,000-meter elevation the average reaches 27.7 meters per second, as compared with the summer mean of 12 m/s. at that level. In Figure 2 the mean seasonal wind directions and velocities have been plotted and the contrast of winter and summer velocities is shown, as also the similarity of autumn and spring velocities. A glance at the graph of directions shows particularly the more consistently west component during the autumn months, with only slight deviation above 1,500 meters from a due west direction. In the other seasons the north component is more generally present, while in no case above 1,500 meters, as stated before, is there any close approach to a south component.

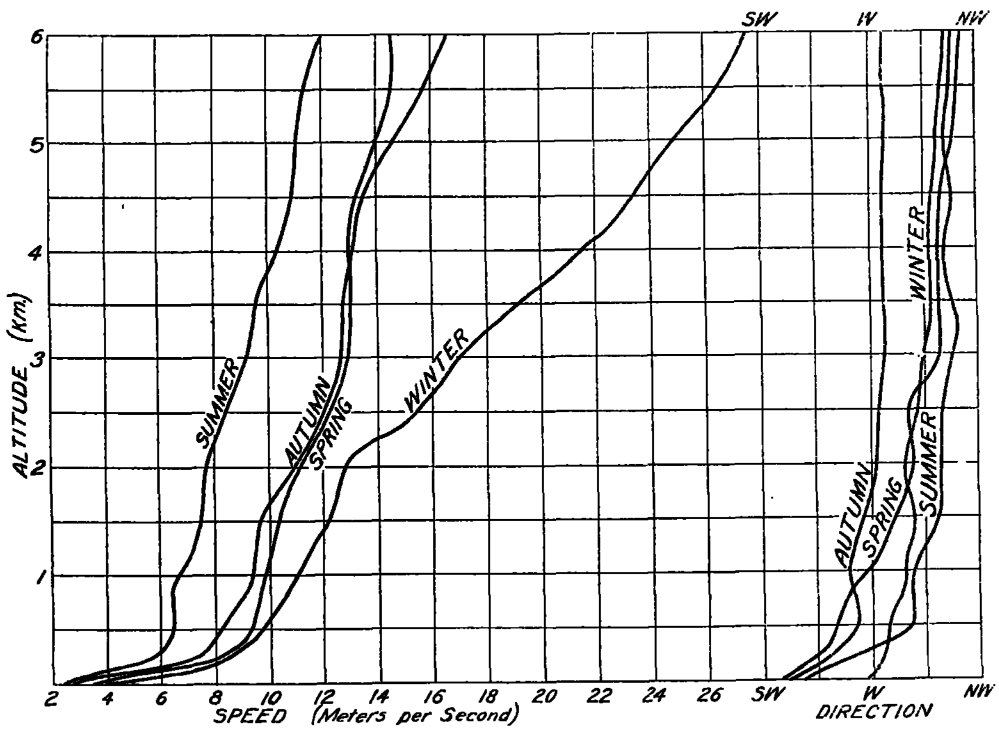

FIGURE 2.—Mean seasonal wind directions and speeds above Lansing, Mich.

TABLE 3.—*Mean free-air winds at Lansing, Mich., June, 1919, to May, 1922, inclusive.*

[Altitude, 262.9 m.; latitude, 42° 44′; longitude, 84° 26′.]

Altitude.	Spring.		Summer.		Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
m.		*m. p. s.*		*m. p. s.*		*m. p. s.*		*m. p. s.*		*m. p. s.*
Surface	S. 55° W.	3.6	S. 63° W.	2.4	S. 56° W.	2.9	S. 88° W.	3.3	S. 66° W.	3.1
250	S. 70° W.	7.8	S. 80° W.	5.8	S. 76° W.	7.6	N. 87° W.	8.0	S. 80° W.	7.3
500	S. 77° W.	9.2	N. 73° W.	6.3	S. 86° W.	8.2	N. 85° W.	9.5	N. 89° W.	8.3
750	S. 79° W.	9.6	N. 73° W.	6.3	S. 79° W.	9.0	N. 83° W.	10.4	W.	8.8
1,000	S. 89° W.	9.8	N. 70° W.	6.4	S. 82° W.	9.4	N. 77° W.	10.8	N. 82° W.	9.1
1,500	N. 83° W.	10.3	N. 64° W.	7.3	S. 89° W.	9.8	N. 73° W.	12.2	N. 78° W.	9.9
2,000	N. 73° W.	11.0	N. 60° W.	7.8	N. 89° W.	10.8	N. 73° W.	12.8	N. 74° W.	10.6
2,500	N. 73° W.	12.0	N. 62° W.	8.4	N. 89° W.	12.0	N. 70° W.	15.5	N. 74° W.	12.0
3,000	N. 64° W.	13.1	N. 58° W.	9.1	N. 83° W.	12.9	N. 68° W.	16.8	N. 68° W.	13.0
3,500	N. 64° W.	13.7	N. 58° W.	9.7	N. 85° W.	13.6	N. 65° W.	18.8	N. 68° W.	14.0
4,000	N. 64° W.	14.9	N. 63° W.	10.2	N. 85° W.	15.0	N. 66° W.	21.7	N. 70° W.	15.4
4,500	N. 66° W.	15.4	N. 58° W.	10.3	N. 86° W.	15.7	N. 61° W.	23.5	N. 66° W.	16.2
5,000	N. 64° W.	16.0	N. 61° W.	11.1	N. 84° W.	16.4	N. 57° W.	24.6	N. 66° W.	17.0
6,000	N. 58° W.	16.8	N. 57° W.	12.0	N. 84° W.	18.5	N. 54° W.	27.7	N. 63° W.	18.8

TABLE 4.—*Average annual direction and speed of free-air winds, Lansing, Mich., for different directions at surface.*

Surface.	Altitude, meters.							
	250	500	750	1,000	2,000	3,000	4,000	5,000
N. 2.3	N. 12° E. 4.9	N. 3° E. 5.3	N. 3° W. 5.8	N. 11° W. 6.3	N. 15° W. 9.2	N. 19° W. 11.6	N. 39° W. 14.5	N. 33° W. 18.1
NNE. 2.7	N. 27° E. 6.0	N. 32° E. 6.3	N. 24° E. 6.5	N. 18° E. 6.2	N. 6° W. 7.0	N. 23° W. 9.2	N. 22° W. 11.5	N. 26° W. 12.4
NE. 2.8	N. 46° E. 6.5	N. 49° E. 7.0	N. 17° E. 6.8	N. 40° E. 6.6	N. 3° E. 7.7	N. 8° W. 8.8	N. 29° W. 11.3	N. 28° W. 12.7
ENE. 2.5	N. 73° E. 5.8	N. 81° E. 6.4	N. 76° E. 6.0	N. 73° E. 6.5	N. 19° E. 6.4	N. 17° W. 7.4	N. 22° W. 9.9	N. 30° W. 12.1
E. 2.6	S. 83° E. 5.9	S. 79° E. 6.7	S. 71° E. 6.3	S. 60° E. 6.2	N. 48° E. 6.0	N. 76° W. 7.5	N. 66° W. 9.4	N. 68° W. 10.6
ESE. 2.2	S. 63° E. 5.8	S. 50° E. 6.0	S. 42° E. 5.8	S. 32° E. 5.9	S. 78° W. 6.6	N. 63° W. 6.5	N. 79° W. 8.9	S. 85° W. 9.7
SE. 2.6	S. 26° E. 6.1	S. 19° E. 6.7	S. 13° E. 6.9	S. 12° E. 6.7	S. 53° W. 7.6	S. 81° W. 9.1	N. 85° W. 11.3	S. 89° W. 13.2
SSE. 2.8	S. 11° E. 7.7	S. 2° W. 8.6	S. 14° W. 8.5	S. 35° W. 7.9	S. 69° W. 8.6	S. 74° W. 11.2	S. 85° W. 13.2	N. 81° W. 14.4
S. 3.3	S. 23° W. 7.6	S. 29° W. 9.4	S. 37° W. 9.5	S. 45° W. 9.7	S. 62° W. 9.6	S. 74° W. 11.8	S. 78° W. 13.9	N. 88° W. 15.7
SSW. 2.9	S. 46° W. 8.4	S. 57° W. 9.8	S. 63° W. 10.7	S. 64° W. 10.8	S. 80° W. 11.6	N. 89° W. 13.7	N. 76° W. 16.7	N. 71° W. 18.1
SW. 3.0	S. 60° W. 8.6	S. 70° W. 9.6	S. 69° W. 10.3	S. 73° W. 10.6	N. 85° W. 11.5	S. 88° W. 13.0	N. 84° W. 15.1	N. 81° W. 17.0
WSW. 3.1	S. 77° W. 8.4	S. 85° W. 9.3	S. 89° W. 10.2	N. 89° W. 10.6	N. 80° W. 12.7	N. 70° W. 15.3	N. 66° W. 17.2	N. 48° W. 18.6
W. 3.5	N. 85° W. 7.8	N. 82° W. 9.3	N. 79° W. 10.3	N. 79° W. 10.9	N. 71° W. 12.2	N. 70° W. 15.6	N. 59° W. 17.9	N. 63° W. 19.7
WNW. 4.0	N. 61° W. 7.9	N. 60° W. 9.5	N. 59° W. 9.2	N. 58° W. 9.9	N. 52° W. 13.0	N. 50° W. 16.6	N. 52° W. 19.2	N. 49° W. 20.9
NW. 3.3	N. 39° W. 6.9	N. 40° W. 8.4	N. 42° W. 8.8	N. 39° W. 9.5	N. 49° W. 13.6	N. 48° W. 17.1	N. 44° W. 20.3	N. 52° W. 22.2
NNW. 3.2	N. 23° W. 5.9	N. 23° W. 6.8	N. 29° W. 7.6	N. 30° W. 8.6	N. 34° W. 11.5	N. 40° W. 15.1	N. 55° W. 18.6	N. 54° W. 20.2

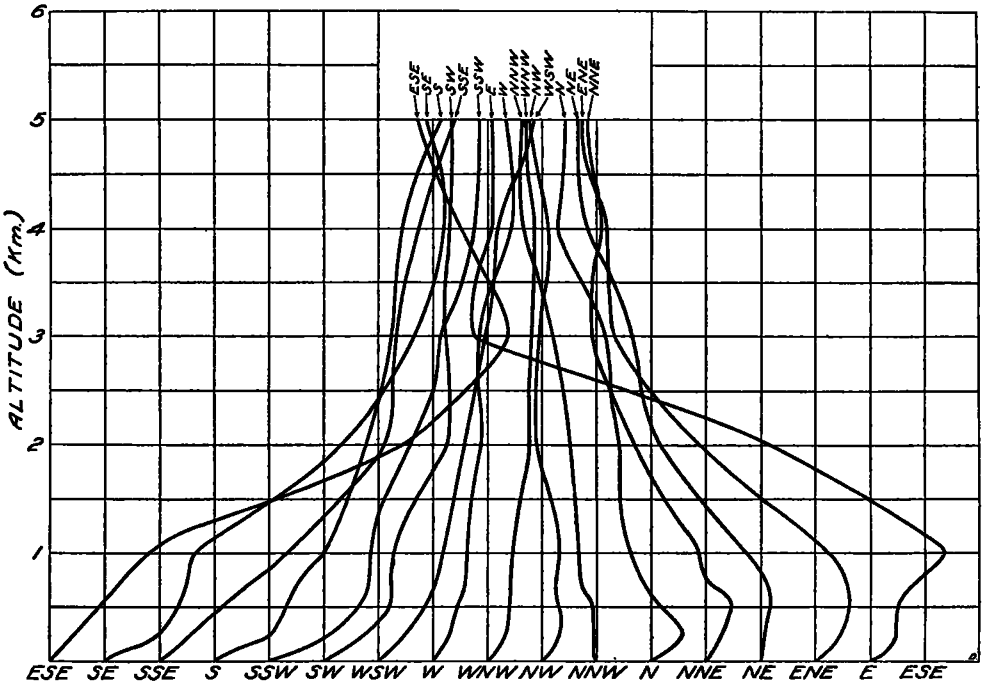

FIGURE 3.—Average turning of various surface winds with altitude above Lansing, Mich.

In Table 4 are given the average direction and velocity at various levels for the 16 directions at the surface. As shown also by similar computations at other stations the increase in velocity from the surface to about 500 meters is approximately the same for all directions. In the upper levels, however, the easterly winds do not reach the velocities attained by the westerlies. Easterly surface winds in most cases shift to west with altitude, the shift occurring frequently between 1,000 and 2,000 meters. Through this shift the velocities are generally small and after reaching a west or northwest current do not usually attain a speed of a wind that has been consistently west from the surface up.

In Figure 3 the tabulated data have been plotted and the relative differences in direction aloft for different surface directions are shown. In the case of surface winds with an east component, the number of flights in several instances is few, and the average direction obtained is probably not entirely dependable. Winds with a surface south component all show a clockwise movement with altitude and as a rule reach a west-southwest direction at about 2,000 meters. Winds with a north-surface component also follow a clockwise direction to about the 500-meter level from which approximate point the drift is counterclockwise. There is a more or less persistent north component to the highest levels, however, the average at 6,000 m. for all winds with a north-surface component being about north-northwest.

TABLE 5.—*Number of flights with different surface directions.*

Meters.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.
250	80	58	73	45	45	42	61	65	110	126	139	105	144	77	106	49
500	74	53	66	42	42	42	56	61	108	124	136	100	137	67	101	45
750	68	50	64	39	41	39	56	59	102	112	128	90	119	56	94	39
1,000	64	46	59	36	40	39	51	54	98	107	122	85	107	48	87	38
2,000	49	36	50	32	34	30	39	45	71	78	95	64	59	26	61	26
3,000	33	28	41	23	26	22	28	36	53	63	66	38	41	16	40	18
4,000	28	18	31	18	22	17	21	28	41	32	42	21	23	10	26	16
5,000	18	12	23	16	18	14	18	19	28	21	30	11	15	7	13	8

A series of flights made between January 24 and 30, 1922, was unusual because of the presence of an east component at the surface in each instance, and because of the comparatively high altitudes attained. The pressure was generally high over the country, with a center of 30.80 inches at Green Bay, Wis., on the 24th, and the temperature at that point −20° F. The only low area present was 30.10 inches in the northwest, centered around Calgary. The high area continued over the eastern half of the country throughout the series of flights, the center moving over the Lakes and thence to New York State. On the 29th, the sixth day of the series, the high area had backtracked apparently and had built up again over the Lakes and Michigan, with a center of 30.70 inches at Sault Ste. Marie. At this time storms had formed in the southern Rockies, with a low center of 29.40 inches at Denver. A summary of the series follows:

TABLE 6.—*Balloon flights, January 24–30, 1922.*

	Jan. 24.	Jan. 25.	Jan. 26.	Jan. 27.	Jan. 28.	Jan. 29.	Jan. 30.
Surface	NNE. 2.2	SSE. 2.7	E. 2.7	NE. 2.7	NNE. 3.1	ENE. 2.7	ESE. 2.2
1,000	NNE. 2.9	SSE. 6.4	SE. 4.7	ESE. 7.5	ENE. 6.7	E. 7.1	SSW. 5.0
2,000	NNW. 8.4	WSW. 4.0	S. 1.3	ENE. 3.2	ENE. 5.6	NE. 6.4	SSW. 9.0
3,000	NNW. 11.2	W. 4.2	SW. 4.0	E. 2.0	NE. 4.1	ENE. 5.0	SSW. 11.8
4,000	NW. 16.2	WNW. 6.3	WSW. 5.0	SW. 1.0	NNE. 3.2	NNW. 2.0	SW. 11.3
5,000	WNW. 24.0	W. 6.0	SSW. 4.5	NNW. 2.0	NNW. 7.0	N. 5.2	SW. 11.8
6,000	WNW. 27.5	WNW. 5.3	SSW. 3.5	....	NNW. 12.3	NNW. 12.0	....
7,000	....	NW. 4.6	WSW. 4.2	....	NNW. 16.0	NW. 22.9	....
8,000	....	NW. 6.3	....	....	WSW. 12.0	WNW. 25.7	
9,000	....	NW. 9.0	....	....	NW. 10.0	WNW. 34.5	....
10,000	....	WNW. 15.2	....	....	....	....	....

Flights of great altitude have been obtained on several occasions, as instanced by that of May 12, 1922, when an altitude of over 15,000 meters was obtained. The winds were light until an elevation of 12,000 meters, at which point the balloon entered a northwest current and velocities increased steadily to 27 m/s. at 15,900 meters' altitude. The weather map showed an area of high pressure of 30 inches over the Great Lakes and Ohio Valley and a low of 29.50 inches at North Platte, Nebr. Reaching high altitudes is largely dependent upon light winds, which in turn usually result from a high-pressure area centered over or near the observing station. The greatly increased velocities indicated above 10 kilometers are probably faulty in some instances, because of a leaking balloon, although many recent double theodolite observations show that accurate results are obtained as a rule up to 15 kilometers, at least.

Several flights with extreme velocities have been recorded. On November 18, 1919, a maximum of 58 m/s. was observed near the 6,000-meter level. A high velocity was reported also from Madison, Wis.; the weather map showed a low area of 29.55 inches over the Great Lakes and a high of 30.40 inches at North Platte, with closely placed isobaric lines and a steep gradient.

On December 17, about a month after the instance noted above, the highest velocity ever recorded at Lansing was obtained, 83 m/s. from the northwest at about 7,000 meters' altitude. A large increase in velocity with altitude was also observed at Madison, Wis., but the balloon was followed only to 2 kilometers where the wind was NW. 26 m/s. The pressure was high with a crest of 30.50 inches at St. Paul and there was a low area of 30 inches moving off the Atlantic coast.[1]

Light winds are recorded more or less frequently during the summer months. On July 4 and 5, 1921, with a high pressure of 30.20 inches over the Great Lakes and down through Illinois, Missouri, and Oklahoma, flights of 9,000 m. and 6,000 m., respectively, were obtained and very light winds prevailed throughout, averaging 3 and 4 m/s. On July 13, 1921, a high pressure of 30.30 inches over the Great Lakes and small gradients gave light air currents up to 10,000 meters, where the balloon was lost.

[1] For more detailed discussion of this high wind see MO. WEATHER REV., 47; 853–854.

An interesting device has been employed at this and several other upper-air stations. A tag is attached to the balloon with request that finder return it, together with any information as to where and when found, was it seen falling, and finder's name and address, so that return may be acknowledged. The tag is of lightweight cardboard, measuring about 2″ by 3″, the additional weight being considered in calculating the total lift. By means of the tag it is possible to obtain interesting data as to the course of the winds after the balloon has been lost to view through clouds or distance. About 10 per cent of the tags are returned, the percentage being greater than that during summer and less in winter. While most of the returns are from points in Michigan, indicating that the balloons generally burst before going any great distance or altitude, there have been a number of reports from Canadian points and from near-by States, West Virginia, Ohio, and Pennsylvania.

One flight of particular interest was made on December 28, 1919. The winds were WNW. at 7,000 meters where the balloon was lost through distance. The tag attached to it was returned from near Rutland, Vt., where the balloon had been picked up. It had not been seen falling. The return was interesting as indicating a southwest current above 7,000 meters, the necessary conclusion, since the course of the winds where the balloon was lost to view would have carried it south of Vermont. Perhaps as many as 25 tags have come back from Ontario, in the brief period since ascensions were started here.

ADDITIONAL NOTE.

By W. R. GREGG.

In the application of free-air data to aviation it is found that increasing importance can be given to *resultant* winds. They have no significance whatever in the case of an individual flight, but, when a regular daily schedule over a considerable period of time, a year for example, is considered, the resultant winds determine what cruising speed an airplane must have in order that a given flight schedule may, on the average, be maintained. Or, to express the same thing in another way, a knowledge of resultant winds will enable a commercial aeronautical firm to bid intelligently on furnishing regular service between two or more points on the basis of the help or hindrance that will, on the average, be experienced from "following" or "head" winds, respectively. Hence it seems appropriate to include resultant wind values in any statistical study of free-air winds. This I have done for Lansing, using for this purpose the figures given in Table 4 of Mr. Ray's paper. The results are given in Table 7, which, for purposes of comparison, contains also wind resultants, previously published,[2] for stations not far distant from Lansing.

TABLE 7.—*Annual resultant winds (m. p. s.) at four stations in North Central United States.*

Altitude above station.	Lansing, Mich.	Royal Center, Ind.	Drexel, Nebr.	Ellendale, N. Dak.
m.				
Surface	S. 72° W. 0.9	S. 53° W. 1.8	S. 37° W. 0.9	N. 48° W. 1.3
250	S. 69° W. 2.6	S. 53° W. 3.5	S. 50° W. 1.5	N. 68° W. 1.8
500	S. 81° W. 3.9	S. 60° W. 4.6	S. 65° W. 2.2	N. 74° W. 2.3
750	S. 84° W. 4.4	S. 65° W. 5.5	S. 74° W. 3.2	N. 75° W. 3.1
1,000	S. 89° W. 5.0	S. 72° W. 6.4	S. 84° W. 4.6	N. 76° W. 3.9
2,000	N. 71° W. 7.8	S. 77° W. 7.8	N. 89° W. 8.1	N. 76° W. 7.5
3,000	N. 69° W. 10.6	S. 83° W. 10.0	N. 86° W. 11.3	N. 75° W. 11.2
4,000	N. 65° W. 13.1	S. 83° W. 11.4	N. 83° W. 13.2	N. 77° W. 12.5
5,000	N. 63° W. 14.5	....	N. 76° W. 14.4	....